UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

December 7, 2007

Tracie Billington
Department of Water Resources
Division of Planning and Local Assistance
P. O. Box 942836
Sacramento CA 94236-0001

RE: Support Letter for AB303 Grant Filing for the Central Basin Groundwater Contamination Study

Dear Ms. Billington:

The U.S. Environmental Protection Agency (EPA) supports the Water Replenishment District of Southern California's efforts to complete the Central Basin Groundwater Contamination Study.

EPA has a keen interest in this study, as it will provide valuable information to help characterize groundwater contamination in the Central Basin and the potential pathways by which this contamination from the shallow aquifers could migrate to the deeper aquifers that are used for potable supply. EPA's Omega Chemical Superfund Site is located within Water Replenishment District's study area, and the data generated would greatly assist EPA in better characterizing the extent and fate of the groundwater contamination in the area and the risk to potential receptors. This information, in turn, could be used to help select the most appropriate remedy to contain and/or remediate the plume originating at the Omega site, as well as to assess the remedy's performance in protecting the groundwater aquifers in the Central Basin.

We fully support the proposed project. Please call me at (415) 972-3174 if you have any questions.

Sincerely,

Frederick K. Schauffler
Chief, Site Cleanup Section 4
Superfund Division

Proposed USGS study of potential pathways for contamination of Central Basin aquifers in the Santa Fe Springs/Whittier area, November, 2004

Background/problem

The Santa Fe Springs- Whittier area of the Central Basin of Los Angeles has multiple contamination sites that have affected shallow ground water. These sites include Omega, Angeles Chemical, McKesson Chemical, Southern California Chemical, Golden Spring Refinery, and Cenco Refinery (fig. A). Investigations of these sites are being conducted/overseen by the USEPA, the California Dept. of Toxic Substances Control (DTSC), and the Regional Water Quality Control Board (RWQCB). Extremely high levels of VOCs have been measured in shallow monitoring wells associated with these sites (e.g. 19,000 ppb of PCE at Omega; 1,500,000 ppb total VOC at McKesson). RWQCB also has inventoried about 60 other sites in the area that are potential sources of ground-water contamination. There are about 30 active production wells in the area that could be affected by the contamination (fig. A). Several of these wells are perforated at relatively shallow depths (less than 200 feet below land surface). More broadly, these shallow contamination sites overlie the main aquifers of the Central basin, which provide about one-third of the drinking-water supply to a population of approximately two million people.

Current investigations are directed towards monitoring and remediation of specific contaminant sites. These investigations address the shallow ground-water system – generally the upper 100-150 ft. A coordinated investigation of the entire area is necessary to properly assess the likely transport mechanisms for contaminants from multiple sources and the cumulative threat to the aquifers providing drinking-water supply. This assessment will guide water managers in determining appropriate monitoring and remediation/prevention actions for the Whittier- Santa Fe Springs area. The assessment also will have transfer value to the other areas of the Central and West Coast Basins where shallow contamination potentially threatens the productive aquifers.

Objectives

The objectives of this study will be to: 1) Utilize existing data, supplemented by limited new chemical analyses, to characterize the hydrogeologic connection between the shallow contaminated aquifers in the Whittier-Santa Fe Springs area and the main drinking-water aquifers of the Central Basin; and 2) Identify/prioritize additional data collection needs.

Relevant Previous studies

In addition to the project reports associated with the individual contamination investigations, there are several relevant reports that address the geohydrology and geochemistry of the Central Basin, including the Santa Fe Springs-Whittier area. These include the original studies by the USGS (Mendenhall, 1905 a,b,c; Poland and others, 1956, 1959) and the California Dept. of Water Resources (1961, 1962). The USGS is currently engaged in several studies of the region. Recent reports detail the data collection (Land and others, 2002) and the geohydrology, geochemistry, and regional ground-water modeling of the Central and West Coast Basins (Reichard and others, 2003; Land and others, 2004). Schroeder (2003), Anders and Schroeder (2003), and Anders and others (2004) detail water-quality impacts of spreading in the Montebello forebay to the northwest of the study area. Dawson-Milby and others (2003) and Shelton and others (2001) analyze the distribution of low-level volatile organics in the regional aquifer systems of coastal Los Angeles. The use of sequence stratigraphic techniques to address ground-water issues coastal Los Angeles is summarized in Hillhouse and others (2002).

Approach

1. Data Compilation/Synthesis

The first task of the study is to bring together the data on the main producing aquifers with the localized data related to the shallow contaminant sites. The USGS and the WRDSC have developed GIS databases of the regional aquifer systems of the Central Basin. These databases will serve as the starting point for the work proposed in this study.

Data on producing aquifers

The USGS, in cooperation with the WRDSC has installed several multiple-well monitoring sites in or near the area. These sites are typically drilled to 1000-1500 ft depths. They have good geologic descriptions, 2-4 3 ft.-long cores per hole, conventional electric logs (SP, resistivity, gamma, EM) from surface to total depth, and 4-6 piezometers per hole with screens of no greater than 20' length to allow for sampling of specific producing zones. Two of these sites lie within the proposed study area (Santa Fe Springs–1, Norwalk-1), and four others are nearby (Rio Hondo-1, Pico-2, Whittier-1, La Mirada-1). Water-quality data have been collected from all of these sites.

There are about 30 active production wells in the proposed study area, and more than 60 other wells that are periodically monitored for water levels and water quality by LA County Dept. of Public Works and other entities. They range from approximately 100 ft to more than 1,000 ft deep. With a few exceptions, these wells have geologic logs that are generally of poor quality, and few are electric logged. However, most of these wells should be available for sampling as part of these studies. Presently, the USGS has in its files driller's logs for more than 50 water wells in the study area that were obtained from

California Department of Water Resources files. These logs are generally of poor quality and many of these wells are likely abandoned.

More than 1,500 oil wells have been drilled in and adjacent to the study area, within the Santa Fe Springs, Leffingwell, and Los Angeles oil fields. These wells range in depth from several thousand to more than 10,000 feet in depth. Stratigraphic information from these wells is generally limited to electric log data on file with the California Division of Oil and Gas (DOG), with some limited paleontologic, structural, and core information. With the exception of the electric logs, much of these data are commonly proprietary, but the USGS has contacts within the oil industry that could help us obtain critical information if such exists. Typically, little data exist within the upper 1000 ft of these wells, but some wells do contain information from as shallow as 100-200 ft. In the early 1980's, the USGS canvassed the DOG files for electric log data within the upper 1000 feet within the Los Angeles basin and did not recover any logs from the Santa Fe Springs region. However, that earlier effort did not have Santa Fe Springs as a priority area so we propose to revisit the existing oil well files in search of information relevant to assessing the character and structure of the producing aquifers.

As part of this study, the USGS will search for other data relevant to the regional aquifer system in the area. Oil-industry seismic reflection data with resolution sufficient to be of use to our study may be available, and other regional geophysical information, such as gravity and magnetic data will also be reviewed. Such information could prove useful in better characterizing the overall geologic structure of the region. Another data-collection task will be to gather better information on the construction of water wells in the area.

Data from shallow contamination sites

A major component of this study will be to bring together the detailed data from the individual contaminant sites — including data from the many shallow monitoring wells — into a single database joined with the regional GIS. This component will involve close cooperation between the multiple entities, including the USGS, WRDSC, USEPA, DTSC, RWQCB, and the cities of Santa Fe Springs, Whittier, and Norwalk. These data include inorganic and organic chemistry, water levels, boring logs, and CPT analyses. Some of these data will be available in digital form, but much of the data may have to be scanned/digitized. Although limited in depth, and therefore their utility for characterizing stratigraphy within the producing aquifers, logs of these wells and borings are numerous and are available from several sources. Geologic descriptions from these logs are generally good, and most logs identify the depth to where water was first encountered. An interpretation of these data in a regional context will be very important to our overall evaluation of the nature of the shallow ground-water systems.

In order to make effective use of this compiled data, it will be essential to be able to visualize the information at multiple scales. GIS-compatible programs (e.g. EarthVision, 3-D analyst) will be utilized for this.

2. Sequence stratigraphic analysis

Geologic Setting, Stratigraphy, and Structure

Surficial deposits that occur in the Santa Fe Springs area are comprised of Holocene and late-Pleistocene-age alluvium derived from the San Gabriel River and local drainages that head in the Puente Hills. In the northern half of the proposed study area, the surficial Holocene deposits that are derived from the Puente Hills are mostly fine-grained (fine sands and silt and are likely of moderate to low permeability. Surficial Holocene alluvium in the western part of the study region near the present location of the San Gabriel River, and in the southern part of the study area is sandier and likely of higher permeability. Deposits within and adjacent to the river channel itself consist of coarse sand or gravel and are of high permeability. Alluvial deposits of late Pleistocene age that are classified as part of the Lakewood Formation occur in the central and southeastern part of the proposed study area. These are dominantly sandy deposits, of probable medium to high permeability, that have been uplifted along the Santa Fe Springs anticline and Norwalk fault. Within this region, deeper producing aquifers are at shallower depth and therefore potentially more vulnerable to near surface contaminants. Alluvial deposits in general are quite variable in their composition laterally and are difficult to correlate with high confidence regionally. This variability also means that areas of vertical mergence among coarse-grained facies of these deposits are difficult to delineate and predict with sparse data. However, major depositional sequences of alluvial deposits, separated by unconformities, can generally be recognized from driller's logs by their generally fining-upward character, and these characteristics can aid in regional correlation.

Pleistocene deposits of marine and coastal origin are known to underlie the alluvial deposits although the depth at which this transition occurs within the region is poorly defined. Coastal and marine deposits typically are more laterally homogeneous, and the coarse-grained components of these units (coastal beaches and channels, dunes, near shore marine, and deltaic deposits) generally comprise the more productive aquifers in the region. In general, the conventionally defined Gaspur (Holocene), Gardena, Exposition, Artesia, and Gage (Lakewood Formation) aquifers are thought to be primarily of alluvial origin (or of mixed alluvial and coastal origin in the case of the Gage aquifer) and extend to depths of approximately 200 ft in this region. The underlying Hollydale, Jefferson, Lynwood, Silverado, and Sunnyside aquifers (San Pedro Formation) are generally thought to be of marine origin and extend to depths of 1000' or more. Active production wells in the area are generally screened over long intervals and tap multiple aquifers.

Recent USGS studies in the Long Beach region suggest that even at depths of more than 1000 feet, many of these presumably extensive marine aquifers can be quite variable and have alluvial or near-shore components within them. Based on electric log signatures from nearby USGS wells, it appears likely that largely non-marine deposits in the Santa Fe Springs area extend to depths of between 300-500 feet, and that thin units of non-marine or coastal origin may even extend to greater depths. This implies greater complexity of the internal architecture of the water-bearing deposits than has been previously assumed, and a greater likelihood for localized areas of vertical mergence between superjacent aquifer systems. A goal of this current effort is to better assess the depositional environment of the water-bearing deposits in the Santa Fe Springs area such that the likelihood for vertical mergence among various aquifer systems can be better assessed.

The proposed study area lies within the northeastern margin of the Los Angeles basin. This is currently a compressional margin and several parallel, presumed recently active, NW-SE trending structures accommodate N-S shortening across the region. Mapped within the proposed study area are the La Habra syncline and the Santa Fe Springs anticline. Along the southwestern margin of the study area is the Norwalk fault and a coincident series of buried folds extending to the west that have been recently attributed to the Puente Hills blind thrust system.

From a hydrologic standpoint, the Santa Fe Springs anticline is potentially the most significant geologic structure in the study area. The fold's geometry at depth is fairly well understood based on oil well data, but the near surface geometry is less well defined. Nevertheless, the California Department of Water Resources geologic model for this region currently shows that major producing aquifers of the San Pedro Formation are at shallower depth in the region of the anticline and tend to merge beneath the anticline crest.

If the Santa Fe Springs anticline was actively deforming during deposition of the overlying alluvial sediment (as is generally thought to be the case), then there are significant implications of this with regard to the potential for vertical migration of surface contaminants. In general, the overlying alluvial packages tend to fine upward and be separated by erosional unconformities. Within the region of the uplifting fold crest, each of the alluvial sequences is likely subject to greater erosion, which will preferentially strip off the finer-grained (upper) portions of these packages. The result of this process is to leave thinner and less extensive low-permeability material along the crest of the fold, thus providing more opportunity for contaminants to move downward into the deeper producing aquifers. This characteristic of reduced aquitard preservation associated with syndepositional folding has been observed in a recent USGS study in the Long Beach region. There, fine-grained deposits overlying the active axis of the Wilmington anticline are largely absent, and seawater contamination originating from near-surface deposits has been observed at depths of greater than 400 feet.

Given that the southwestern extent of the known Omega Chemical contaminant plume extends to the Santa Fe Springs anticline crest in the shallow subsurface (fig. A), particular attention will be focused on this structure with respect to its potential for promoting downward migration of contaminants into the central basin aquifers.

New stratigraphic analysis

Previous studies have addressed the hydrostratigraphy of the major regional aquifers/aquifer systems near the Santa Fe Springs - Whittier area (California Dept. of Water Resources, 1961; Reichard and others, 2003). In addition, several detailed shallow sections have been constructed as part of the investigations of the individual contaminant sites. In this proposed study, all the compiled local and regional data will be utilized to characterize the hydrostratigraphy from the land surface down through the underlying main aquifers. Specifically, the USGS will use sequence stratigraphic methods to correlate deposits and better determine the likely continuity of permeable sediment – which would create pathways for contaminant transport to deeper aquifers. The sequence stratigraphy will be applied in a manner similar to that used in the Dominguez Gap area of the adjacent West Coast Basin (Hillhouse and others, 2002).

The first step will be to integrate the newly compiled data into a generalized sequence stratigraphic framework for the region. This includes classification of the strata into regionally correlative sequences, and characterization of the physical properties of these sequences to the degree that available data allows. The second step will be to construct one or more geologic cross sections parallel to ground-water flow directions, showing the location of major sequence boundaries, the distribution of lithologies, and the relationship between these features and the existing aquifer framework and nomenclature. These sections will then be used as a static geologic framework for assessing the potential for migration of near-surface contaminants into the producing aquifer systems.

3. Water-quality sampling and geochemical assessment

While the emphasis of this project is on utilizing existing data, selected new water-quality data will be collected from: 1) the shallow monitoring associated with contaminant sites; 2) deep multiple-well monitoring sites; and 3) production wells. The strategy will be to sample for specific constituents in production wells and deep monitoring wells that will allow correlation with existing data from the shallow monitoring wells and vice versa.

Initially, selected wells will be sampled and analyzed for low-level VOCs, characterization of dissolved organic carbon (DOC), stable isotopes of oxygen and hydrogen, and selected inorganic constituents. Within the scope of this study, about 20 wells will be sampled (8 shallow monitoring wells, 8 deep monitoring wells, and 4 production wells). The exact set of wells and analyses will be determined after evaluating the existing data. It is possible that fewer wells may be sampled, but analyzed for a broader suite of constituents. Possible additional analyses that could be considered include tritium-helium isotopes, carbon isotopes, selected trace metals, fractionation and optical characterization of DOC, chlorofluorocarbons (CFCs), selected phospholipids and fatty acids, gasoline oxygenates and BTEX compounds, chloride-37, and strontium-87. The low- level VOC analysis considers 85 compounds at part-per-trillion levels. This type of analysis has proven useful for assessing the vulnerability of productive aquifers in the Los Angeles Basin and elsewhere (Shelton and others, 2001; Dawson-Milby and others, 2003). An important aspect for this study will be to establish background VOC concentrations in the main aquifers. Selected major and minor ion data will be used to discern chemically distinct waters and identify water-mineral reactions along flow paths. The stable isotope data provide information on the source of ground-water recharge and distinguish ground-water flow paths. In the USGS regional study of the Central and West Coast Basins (Reichard and others, 2003, Land and others, 2004), stable isotope data has proven useful in identifying indicate multiple sources of recharge to different aquifers. For example, the deepest aquifers may contain paleo-aged water that is isotopically light; shallow aquifers may contain locally recharged water that is isotopically heavy; and perched aquifers may contain isotopically heavy water that has been affected by evaporation. Tritium (and tritium-helium, CFC, and carbon-isotope) analyses are used for dating of time since recharge.

Details of the quality control procedures that will be followed in the collection, measurement, and processing of water-quality sampling are provided in the appendix.

4. Characterization of ground-water flow system

Previous USGS work has provided information on the general flow system within the main aquifers in the Santa Fe Springs- Whittier area (Reichard and others, 2003). The regional ground-water flow model shows ground water flowing south-southwest from the Puente Hills. Stable isotope data from a very limited number of wells in the area also indicate that the main aquifers are predominantly recharged from local sources (e.g. the Puente Hills). Tritium and carbon data indicate that water in the deeper aquifers is "old" water (greater than 50 years old and, in some cases, much older).

In this study, water-level data from the shallow monitoring wells will be compiled in order to more systemically assess the shallow flow regime. The shallow water-level data also will be combined with that from the main aquifers to assess and visualize the three-dimensional gradient field in the area.

Quantitative evaluation of the detailed three-dimensional ground-water flow field requires a ground-water simulation model that incorporates the appropriate scale of hetereogeneity. While development of such a model is beyond the scope of this study, this study will formulate a set of specific recommendations for how such a model should be set up within the framework of the existing regional flow model. These recommendations will be based on the sequence stratigraphic analysis, the geochemical analysis, and the three-dimensional water-level evaluation.

5. Prioritization of data needs

The main goal of the proposed study is to make the best use of existing data, supplemented by targeted new sampling. Combining separately collected data sets from individual contaminant sites and the regional aquifer system provides a much-improved basis for evaluating contaminant migration pathways. Analysis of this integrated data set also will help identify data gaps. A product of this study will be prioritized list of data needs. Note that this data prioritization is nested within tasks 2-4.

Products

The database assembled in this project, including the new water-quality data, will be made available to all relevant stakeholders in the study area. A draft report presenting the results from all tasks will be completed and delivered to stakeholders.

Work plan

Work will be conducted over a one and a half-year period, October 1, 2005 through April 1, 2007.

Task	Oct. 1, 2005 – Sept. 30, 2006		Oct. 1, 2006 – Apr. 1, 2007
1.Data Compilation			
Oil wells	x---------------	-----------------	
Seismic	x---------------	-----------------	
Water	x---------------	-----------------	
Data management	x---------------	-----------------	-----------------
2. Sequence stratigraphic analysis			
Borehole/seismic		x---------------	-----------------
Strat. Framework		x---------------	-----------------
Strat. Sections		x---------------	-----------------
Data needs prioritization & draft report		x--------------	----------------
3. Water-quality sampling and geochemical analysis			
Sample collection	x---------------	-----------------	
Geochemical analyses		x---------------	-----------------
Data needs assessment & draft report			x---------------
4.Characterization of ground-water flow system			
Assessment of ground-water flow field		x---------------	-----------------
Recommendations for model development			x---------------
Data needs prioritization &			x---------------

draft report			

Personnel

DBS – data base specialist; SG = senior geologist; LGC- lead geochemist; FT - field technician; SH-senior hydrogeologist.

Task	Federal Fiscal Year 2006	Federal Fiscal Year 2007
1.Data Compilation		
Oil well compilation	DBS-160 hours($49.50/hr) SG-80 hours($90/hr)	
Seismic compilation	DBS-238 hours($49.50/hr) SG-80 hours($90/hr)	
Water chemistry compilation Data base management	DBS-220 hours($77/hr)	DBS-170 hours($81/hr)
2. Sequence stratigraphic analysis		
Borehole/seismic interpretations	SG-348 hours ($90/hr)	SG-120 hours ($95/hr)
Strat. Framework development	DBS-80 hours($49.50/hr) SG-80 hours($90/hr)	SG-147 hours($95/hr)
Development of strat. Sections	DBS-38 hours($49.50/hr) SG-140 hours($90/hr)	DBS-46 hours($52/hr) SG-80 hours($95/hr)
Data needs prioritization and draft report		SG-240 hours($95/hr)
3. Water-quality sampling and geochemical analysis		
Data collection &processing	FT-141 hours ($57.hr) LGC-270 hours ($82/hr)	
Geochemical analyses	LGC-220 hours ($82/hr)	LGC-198 hours ($86.hr)
Data needs prioritization and draft report		LGC-232 hours ($86.hr)
4.Characterization of ground-water flow system		
Assessment of 3-dimensional Ground-water flow field	SHG-170 hours ($135/hr)	
Recommendations for new model Development		SHG-70 hours ($144/hr)
Data needs prioritization and draft report		SHG-104 hours ($144/hr)

Budget

		2006	2007
1. Data Compilation			
	Labor		
	Oil well compilation	15000	
	Seismic compilation	19000	
	Water/chemistry compilation	17000	
	Data base management		14000
	LABOR TOTAL	51000	14000
	Travel	6000	3400
	Reproduction/digitization	10000	
	TOTAL FOR TASK	**67000**	**17400**
2. Sequence stratigraphic analysis			
	Labor		
	Borehole/seismic interpretations	31200	11400
	Stratigraphic framework development	11100	14000
	Development of stratigraphic sections	14500	10000
	Data needs prioritization and completion of draft report		22800
	LABOR TOTAL	**56800**	**58200**
	Travel		**1400**
	Data processing % computer-related costs	**1400**	**4200**
	TOTAL FOR TASK	**58200**	**63800**
3. Water-quality sampling and geochemical analyses			
	Labor		
	Data collection (field work) and processing	30000	
	Geochemical analyses	18000	17000
	Data needs prioritization and completion of draft report		20000
	LABOR TOTAL	**48000**	**37000**
	Laboratory analyses	**32100**	
	Travel/field supplies	**18100**	**4400**
	TOTAL FOR TASK	**98200**	**41400**
4. Characterization of ground-water flow system			
	Labor		
	Assessment of 3-dimensional ground-water flow field	23000	
	Recommendations for model development		10000
	Data needs prioritization and completion of draft report		15000
	LABOR TOTAL	**23000**	**25000**
	Travel	**1000**	**1000**
	TOTAL FOR TASK	**24000**	**26000**
ANNUAL TOTALS		**247400**	**148600**

The total cost of the study is $396,000. Of this amount, $55,600 would be covered by in-kind salary provided by the USGS and $90,400 would be requested from the Water Replenishment District of Southern California.

Possible future phases of work

The tasks and products presented here are considered a first phase of work. Depending on the results of this first phase, a second phase could involve: publishing the draft report as a formal USGS report; initiation of selected new data collection; and incorporation of the revised hydrostratigraphy into a new/revised ground-water flow and transport model.

References

Anders, R.A., and Schroeder, R.A., 2003, Use of water-quality indicators and environmental tracers to determine the fate and transport of recycled water in Angeles County, California: U.S. Geological Survey Water-Resources Investigations Report 03-4279.

Anders, Robert, Yanko, W.A., Schroeder, R.A., and Jackson, J.L., 2004, Virus Fate and Transport During Recharge Using Recycled Water at a Research Field Site in the Montebello Forebay, Los Angeles County, California, 1997-2000: U.S. Geological Survey Scientific Investigations Report 2004-5161.

California Department of Water Resources, 1961, Planned utilization of the ground water basins of the coastal plain of Los Angeles Country, Appendix A, Ground water geology: California Department of Water Resources Bulletin 104, 191 p

________________ 1962, Planned utilization of the ground water basins of the coastal plain of Los Angeles Country, Appendix B, Safe yield determinations: California Department of Water Resources Bulletin 104, 129 p.

Dawson-Milby, B.J., Belitz, Kenneth, Land, Michael, and Danskin, W.R., 2003, Stable isotope and volatile organic compounds along seven ground-water flow paths in divergent and convergent flow systems, Southern California, 2000: U.S. Geological Survey, Water-Resources Investigations Report 03-4059, 79p.

Hillhouse, J.W., Reichard, E.G., and Ponti, D.J., 2002, Probing the Los Angeles Basin – Insights into ground-water resources and earthquake hazards: U.S. Geological Survey Fact Sheet 086-02, 2 p.

Land, Michael, Everett, R.R., and Crawford, S.M., 2002, Geologic, hydrologic, and water-quality data from multiple-well monitoring sites in the Central and West Coast Basins, Los Angeles, County, California, 1995–2000: U.S. Geological Survey Open-File Report 01-277, 178 p.

Land, Michael, Reichard, E.G., Crawford, S.M., Everett. R.R., Newhouse, M.W., and Williams, C.F., 2004, Ground-Water Quality of Coastal Aquifer Systems in the West Coast Basin, Los Angeles County, California, 1999-2002: U.S. Geological Survey Scientific Investigations Report 2004-5067.

Mendenhall, W.D., 1905a, Development of underground waters in the eastern coastal plain region of southern California: U.S. Geological Survey Water Supply Paper 137, 140 p.

________________1905b, Development of underground waters in the central coastal plain region of southern California: U.S. Geological Survey Water Supply Paper 138, 162 p.

________________1905c, Development of underground waters in the western coastal plain region of southern California: U.S. Geological Survey Water Supply Paper 139, 103 p.

Poland, J.F., Piper, A.M., and others, 1956, Ground water geology of the coastal zone, Long Beach Santa Ana area, California: U.S. Geological Survey Water-Supply Paper 1109, 162 p.

Poland, J.F., Garrett, A.A., and Sinnot, A., 1959, Geology, hydrology, and chemical character of ground waters in the Torrance-Santa Monica area, California: U.S. Geological Survey Water Supply Paper 1461, 425 p.

Reichard, E.G., Land, Michael, Crawford, S.M., Johnson, Tyler, Everett, R.R., Kulshan, T.V., Ponti, D.J., Johnson, T.A., Paybins, K.S., and Nishikawa, Tracy, 2003 Geohydrology, geochemistry, and ground-water simulation-optimization of the Central and West Coast Basins, Los Angeles, County, California: U.S. Geological Survey Water Resources Investigations Report 03-4065, 184 p.

Ludtke, A.S., Woodworth, M.T., 1997, USGS blind sample project: monitoring and evaluating laboratory analytical quality: Fact Sheet 136-97, 1 p.

Pirkey, K.D., and Glodt, S.D., 1998, Quality control at the U.S. Geological Survey, National Water Quality Laboratory: Fact Sheet 026-98, 4p.

Schroeder, R.A. (editor), 2003, Water-quality changes and organic-carbon characterization during recharge with recycled water at a Research Basin in Montebello Forebay, Los Angeles County, California, 1991-1996. U.S. Geological Survey, Water-Resources Investigations Report 03-4146.

Shelton, J.L., Burrow, K.R., Belitz, Kenneth, Dubrovsky, N.M., Land, Michael, and Gronberg, J.M., 2001, Low-level volatile organic compounds in active public supply wells as ground-water tracers in the Los Angeles physiographic basin, California, 2000: U.S. Geological Survey, Water-Resources Investigations Report 01-4188, 29p.

Stanley, D.L., Boozer, T.M.,Schroder, L.J., 1998, Summary of the U.S. Geological Survey National Field Quality Assurance Program from 1979 through 1997: U.S. Geological Survey Open-File Report 98-392, 11 p.

U.S. Geological Survey, variously dated, National field manual for the collection of water-quality data: U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chaps. A1-A9 (http://pubs.water.usgs.gov/twri9A).

Ziony, J. I. ed., 1985, Evaluating earthquake hazards in the Los Angeles Region – an earth science perspective: U. S. Geological Survey Professional Paper 1360, 505p.

Appendix: Quality control procedures

Collection, measurement, and processing of field samples will follow procedures outlined in the USGS National Field Manual for the Collection of Water-Quality Data (http://pubs.water.usgs.gov/twri9A). All USGS field personnel who perform water-sample measurements of specific conductance, alkalinity, and pH are required to demonstrate their proficiency in making these measurements by participating in the USGS National Field Quality Assurance Program (Stanley and others, 1998)

Three kinds of field quality-control samples (blanks, replicates, and spikes) will be collected. Blank samples are collected and processed using specially prepared analyte-free water to identify potential sources of contamination in the sampling process that could lead to a positive bias in the data. Replicates are two or more samples collected and processed so that the samples are as identical in composition as possible in order to provide a measure of data variability introduced during sample collection, processing, and analysis. Spike samples are made by adding solutions containing known amounts of VOCs to replicate ground-water samples. Spike recoveries for these analytes are used to evaluate bias of the analytical results related to matrix interferences or methods of sample collection and analysis. The frequency of collection of each QC sample will be determined on the basis of project needs once the number and type of wells have been finalized.

The USGS National Water Quality Laboratory (NWQL) will be the analytical facility for most samples collected in this study. Quality assessment procedures—including quality-assurance elements and quality-control data—at the NWQL are described by Pirkey and Glodt (1998). The NWQL collects laboratory quality-control data on a continuing basis to determine long-term method detection levels (LT-MDL) and laboratory reporting limits (LRL). The USGS also operates an independent, external, quality-assurance project called the Inorganic Blind Sample Project (IBSP) to monitor and evaluate the quality of laboratory analytical results through the use of double-blind QC samples. Results from the project can be used to estimate the extent that laboratory errors contribute to overall errors in environmental data (Ludtke and Woodworth, 1997).

Figure 1 - Index Map

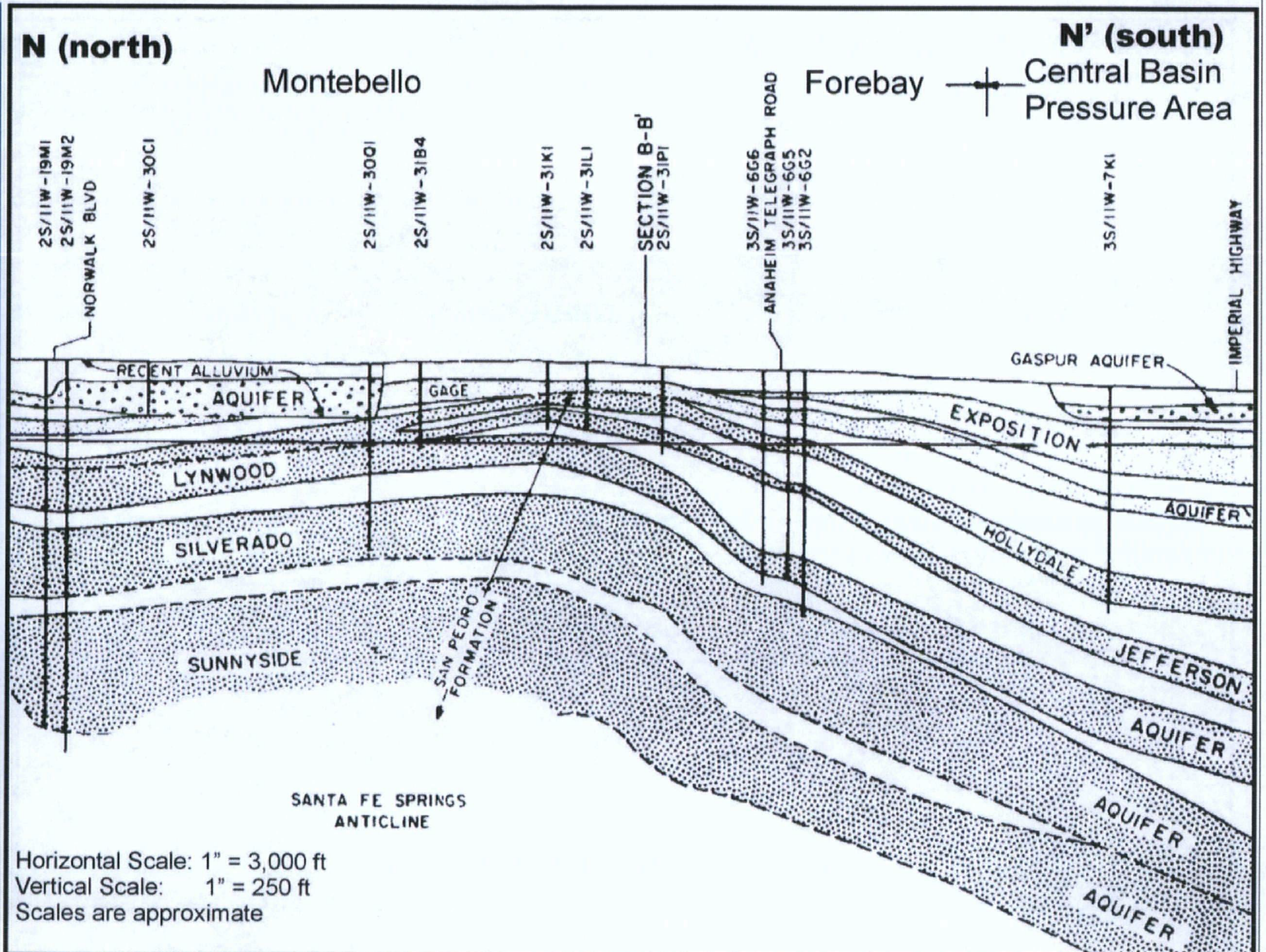
WA-Controlled/Critical Infrastructure-Water Assessments

[redacted]

WA-Controlled/Critical Infrastructure-Water Assessments

[redacted]

Cross Section N-N'



Modified from DWR Bulletin 104 (1961)

Figure 4